NOTES

Some effects of different forest litters on seed germination and growth

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Germination and growth of 12 native herbs, shrubs, and trees were followed in five litter components characteristic of successional stages of the northeastern Minnesota forest. Various litter components stimulated or inhibited seed germination and seedling growth of some species. Germination and growth were not always similarly affected, suggesting that different factors may be involved. Inhibition and lack of inhibition of some species on certain litter components correlate with natural habitat preferences of these species and the nature of the litter in these habitats. This information can be of use in improving results of seeding for site reclamation and reforestation.

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La germination et la croissance de 12 espèces indigènes herbacées, arbustives et arborées furent suivies sur cinq types de litière caractérisant les stades évolutifs de la forêt du nord-est du Minnesota. Certains types de litière ont stimulé ou inhibé la germination des graines et la croissance des semis de quelques espèces. La germination fut quelquefois affectée différemment de la croissance, ce qui suggère l'implication de facteurs différents. La présence ou l'absence d'inhibition de quelques espèces sur certains types de litière est en corrélation avec les habitats préférés de ces espèces et avec la nature de la litière dans ces habitats. Ces renseignements peuvent être utiles pour l'amélioration des résultats d'ensemencement pour la reconstitution des sites et le reboisement.

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Introduction

Forest litter has long been recognized as a possible deterrent to tree seedling establishment (Koroleff 1954), and differences in germination and growth of a number of herbs, shrubs, and trees beneath trees of various species are well-known (Telfer 1972; Ovington 1955). Forest litter and the soil immediately below it contain viable seeds of many species (Ahlgren 1979*a*, 1979*b*, 1979*c*). Germination and subsequent growth of these seeds may be controlled in part by litter, as well as by other factors such as moisture, heat, light, nutrients, wildlife, and competition. The extent of these litter influences on plant succession in the northern Great Lakes area forest has not been investigated. However, this forest is characterized by a slow litter biomass turnover in the undistrubed state and by a forest succession pattern based on recurring disturbances, notably fire and blowdown. These disturbances, which often destroy both canopy and litter, occur with sufficient frequency that a true climax forest is rarely achieved.

An understanding of the role of litter in such successional patterns is important in interpreting, preserving, and managing these forests. For example, post-settlement acreage reduction of some heavy litter-producing species such as red pine (*Pinus resinosa* Ait.) and white pine (*P. strobus* L.) may already have influenced natural succession. Forest litter changes may also affect the introduction and establishment of weeds and other species into natural and wilderness areas. The use of certain species as indicators of site must also be evaluated with knowledge of the possible effects of forest litter on species distribution and growth.

Litter can affect seed germination and seedling growth by altering insulation, soil temperature, and pH, by changing availability of moisture and nutrients, and by allelopathic influences. Allelopathy is now recognized as an important factor in forest succession (Rietvald 1979). Comprehensive reviews of the many papers on forest allelopathy cite studies identifying

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allelopathic substances, mechanisms of action, and various species involved (Rice 1974, 1979; Horsley 1977*a*). Few, however, deal with litter or with species present in the northern Great Lakes area forest. Brown (1969) found both stimulation and inhibition of jack pine (*Pinus banksiana* Lamb.) germination and growth by extracts of certain native herbs, shrubs, mosses, and ferns. Dawes and Maravolo (1973) found that orange hawkweed (*Hieracium aurantiacum* L.) inhibited germination and growth of balsam fir (*Abies balsamea* (L.) Mill.) and white pine. Some native ground cover plants (*Pteridium aquilinum* (L.) Kuhn), *Symphoricarpos alba* (L.) Blake), *Lycopodium obscurum* L., *Cladonia* spp., *Cornus canadensis* L., *Aster umbellatus* Mill.), while not tested on northern Great Lakes area species, have been found allelopathic to those species native to other forest areas (Rice 1974, 1979; del Moral and Cates 1971; Horsley 1977*a*, 1977*b*). Norby and Kozlowski (1980) report inhibition of red pine radicle elongation and seedling growth by extracts of *Aster macrophyllus*, *Lonicera tatarica*, *Solanum dulcamara*, *Solidago gigantea*, *Prunus serotina*, and *Rubus idaeus* var. *strigosus*. We suggest that litter type may influence germination and growth of seedlings native to the forests of northeastern Minnesota, especially the Boundary Waters Canoe Area Wilderness where this study was conducted.

This paper is a report on the germination and early seedling growth of 12 common herbs, shrubs, and trees in five litter components characteristic of successional stages of northeastern Minnesota forests. This report, however, does not distinguish among physical, nutritional, chemical, and allelopathic influences.

Methods

Red pine and white pine needles were gathered from the ground under trees of each of these species. It is difficult to obtain litter of just one species of deciduous trees and conifers with small needles from the forest floor because of the mixing of leaves of associated tree and herb species and the more rapid breakdown of such material. Therefore, aspen (*Populus tremuloides* Michx.), paper birch (*Betula papyrifera* Marsh.), and balsam fir branches were gathered from trees in midsummer, air dried in an open shed for 2½ to 3 weeks, and the leaves and needles collected. Leaves and needles were ground in a Universal food mill, passed through a 10-mesh sieve, and mixed with sterile potting soil and clean sand (5 parts soil, 5 parts foliage, 2 parts sand). This mixture approximated the original condition of the soil layer in which seeds germinate. Lacking an organic additive that has been established as completely inert chemically, no substitute for litter was added to the control; a mixture of 5 parts soil and 2 parts sand was designated as the control. Because these litter additives and the lack of them in the control produced differences in soil texture, chemical content, moisture relationships, and allelopathic substances, resultant differences in germination and growth cannot be attributed solely to any one of these altered characteristics. They do, however, give an indication of the extent of these litter influences.

Seeds were collected as they matured and stored at 4.4°C until planted. Most seeds were planted in August in plastic containers with perforated bases. Red pine, white pine, and *Aster macrophyllus* L. were planted in September when mature seed became available. All seeds of one species were planted on the same day. Four 25-seed replicates, or a total of 100 seeds, were planted for each seed–litter type combination. Containers were placed in a cold frame until February 1 when they were brought indoors and placed under fluorescent lights for 14-h days with night temperatures of 17°C and day temperatures of 20°C for 2 months. Containers were sprinkled with tap water when soil surfaces began to dry.

Seed germination was recorded at weekly intervals during September, October and February, March, and April. At the end of this time, above ground parts of the five largest seedlings of each combination were harvested, dried at 100°C for 48 h, and weighed. This sample size was the largest number that could be obtained for all species. A one-way analysis of variance of the arc-sine transformed germination values was used to determine significance of germination results.

Results

Total seed germination

Germination differed by species in the various litter types (Table 1). *Galium triflorum* Michx. germination was lower in all litters than in the control. Some but not all litters were associated only with seed germination reduction of *Cerastium vulgatum* L., *Caltha palustris* L., *Aster macrophyllus*, jack pine, red pine, and white pine. These reductions differed for each of the species. Germination of *Ranunculus acris* L. seed was higher in all litters than in the control. However, germination was higher only in certain litters for seeds of northern white cedar (*Thuja occidentalis* L.), white spruce (*Picea glauca* (Moench.) Voss), and *Lonicera canadensis* Bartr.

All litter types were associated with increased germination of seed of at least some species, decreased germination of others, and no significant change in still others. However, seed of species which were inhibited by some litter types were not stimulated by any others. Conversely, seeds of those species stimulated by some litters were not inhibited by any others. The only exception was *Mitella nuda* L. which showed a slight increase in germination (significant only at the 5% level) in one litter and a reduction in the others. Total seed germination of all species combined was noticeably lower in birch and balsam fir litter types than in the others. Total germination in white pine litter was high and very similar to germination in the soil control. In no case was all germination eliminated by any litter type.

Other tests made earlier showed similar trends, but germination samples were reduced by rodent damage

TABLE 1. Total seed germination of 100 seed samples in various litter–soil mixtures and in unmixed soil (control)

Species of seed	Unmixed soil control	Litter type				
		Quaking aspen	White birch	Red pine	White pine	Balsam fir
Galium triflorum	87	46**	9**	20**	10**	6**
Cerastium vulgatum	42	17**	24	13**	4**	1**
Mitella nuda	47	65	14**	15**	16**	5**
Caltha palustris	85	71	66	64	69	46**
Ranunculus acris	43	78**	78**	84**	80**	74**
Aster macrophyllus	46	20**	33	53	48	30
Lonicera canadensis	37	78**	35	70**	71**	29
Pinus banksiana	71	33**	23**	60	72	42**
Pinus resinosa	66	48	15**	42	77	24**
Pinus strobus	93	67**	52**	76	92	43**
Thuja occidentalis	22	75**	23	86**	51**	74**
Picea glauca	16	39**	14	59**	62**	44**
Total germination	655	637	386	642	652	418

**Significant at 1% level.

TABLE 2. Germination rate in litter–soil mixtures and in unmixed soil (control). Date given (month/day) indicates time at which 50% or more of total germination was achieved

Species of seed	Unmixed soil control	Litter type				
		Quaking aspen	White birch	Red pine	White pine	Balsam fir
Galium triflorum	9/16	9/16	2/21	9/16	9/16	9/16
Cerastium vulgatum	9/16	2/12	2/12	2/12	9/16	2/12
Mitella nuda	2/12	2/27	3/6	3/6	3/6	3/31
Caltha palustris	2/21	2/21	2/21	2/21	2/21	2/21
Ranunculus acris	2/21	2/21	2/21	2/21	2/21	2/21
Aster macrophyllus	3/3	3/3	3/3	3/3	3/3	3/3
Lonicera canadensis	9/16	9/16	10/4	10/4	10/4	2/12
Pinus banksiana	2/21	3/6	3/17	2/21	2/21	2/27
Pinus resinosa	2/21	2/27	3/17	3/17	3/6	3/17
Pinus strobus	2/21	2/21	2/21	2/27	2/21	3/6
Thuja occidentalis	2/21	2/21	2/21	2/21	2/27	2/27
Picea glauca	3/8	3/8	3/8	3/3	3/3	3/3

and hence not included here. Other species for which germination was too low for statistical analysis but for which trends were evident were *Corydalis sempervirens* (L.) Pers. with reduced germination in all litters, *Aquilegia canadensis* L., and balsam fir with reduced germination in all conifer litters.

Germination rate

Germination was slower in some litter types than in the control. It was never accelerated in litter (Table 2). For example, *Cerastium* germination was delayed from mid-September until when removed from the cold frame in February in all litters except white pine. Spring-germinating species were delayed from 1 to about 4 weeks in some litters, Germination rates of white spruce, cedar, *Ranunculus*, *Caltha*, and *Aster* were relatively unaffected in any litter types. Variations in rates of germination and in total germination varied independently (cf. Tables 1 and 2). For example, total germination of *Galium* seed was reduced in all litters, but *Galium* germination rate was unaffected except in birch litter. In contrast, total germination of *Ranunculus* seed was higher in all litters than in soil, but the rate was similar in all.

TABLE 3. Dry weight (grams) of above ground parts. Each sample contained five plants

Species of seed	Unmixed soil control	Litter type				
		Quaking aspen	White birch	Red pine	White pine	Balsam fir
Galium triflorum	0.1921	0.3745	0.0249	0.0069	0.0073	0.0005
Cerastium vulgatum	0.0729	0.0621	0.0161	0.0032	0.0050	0.0040
Mitella nuda	0.0629	0.0784	0.0037	0.0006	0.0019	0.0009
Caltha palustris	0.0400	0.0238	0.0275	0.0133	0.0169	0.0129
Ranunculus acris	0.0662	0.0285	0.0424	0.0276	0.0162	0.0123
Aster macrophyllus	0.0575	0.0083	0.0200	0.0057	0.0243	0.0074
Lonicera canadensis	0.1079	0.0529	0.0573	0.0360	0.0271	0.0469
Pinus banksiana	0.0356	0.0072	0.0400	0.0075	0.0237	0.0207
Pinus resinosa	0.0694	0.0143	0.0433	0.0146	0.0277	0.0233
Pinus strobus	0.0641	0.0389	0.0665	0.0379	0.0769	0.0438
Thuja occidentalis	0.0137	0.0078	0.0180	0.0042	0.0079	0.0253
Picea glauca	0.0105	0.0072	0.0184	0.0048	0.0287	0.0167
Total biomass	0.7928	0.7039	0.3781	0.1623	0.2636	0.2147

Phytomass

Dry weight of seedlings harvested 3 months after removal from the cold frame was used as an indication of the possible effects of litter on seedling growth (Table 3). Since only one composite seedling sample from each species–litter type combination was available, statistical significance could not be established. However, noticeable differences are evident, especially cases in which there is less growth on some litters than on the control. Increased growth in litter was less frequent. Alterations in growth did not necessarily correspond with changes in germination, although sometimes the effects were similar. Percent germination of *Ranunculus* seed, for example, was greater in all litters than in the control, while its phytomass was lower in all litters. Germination and growth of *Mitella*, in contrast, were both lower in all litters except in aspen where they both were higher than in the control.

Total phytomass of all species combined was highest in the control and in aspen litter and was much reduced in the other litters. Total phytomass was lowest in red pine litter, while total seed germination was lowest in birch and balsam fir litters.

Discussion

Seed germination and seedling growth were variously influenced by leaf litter of several species common to forests of northeastern Minnesota. These effects varied with both seed and litter species. Germination and growth were not always similarly affected, suggesting that different factors of the litter may be involved in controlling germination and in controlling growth.

Results with several species reveal relationships with the habitat preferences of those species. For the shade-tolerant northen white cedar and white spruce, seedlings of which are common in dense balsam fir forests, seeds germinated better in balsam fir litter than in the control or other litters. This suggests that the occurrence of these species in balsam fir stands may be dependent in part on the litter type and not just their shade tolerance. White pine germinated and grew best in white pine litter, suggesting a potential to be self sustaining in the undisturbed forest. While white pine seedlings and saplings are often abundant in old white pine stands, in northern Minnesota blister rust destroys most of them. Red pine, in contrast, germinated and grew poorly in its own and several other litters, reflecting its requirement of mineral soil seedbeds for natural seedling establishment. Norby and Kozlowski (1980) report the sensitivity of red pine to leaf extract of a number of species and suggest an allelopathic relationship. *Aster macrophyllus*, characteristic ground cover species of pine forests, germinated best in pine litter. *Mitella*, a ground cover plant in several forest types, grows most abundantly and fruits best in the aspen forest. Its germination, germination rate, and growth were inhibited by all litters except aspen.

In nature, the effects of litter, whether physical, chemical, or allelopathic, would be influenced in part by other environmental factors and other components of forest litter in synergistic relationships. Therefore, an accurate assessment of the effects of these litters in the field must involve studies in plant distribution. Correlation of data from our 28-year study of plant succession in the area with results reported here is in process.

This study was not designed to determine whether the litter factors involved in the reported differences are of allelopathic, physical, or chemical nature. Further experiments will be required to do this. Results do indicate, however, that litter components influence seed germination and seedling growth and that these influences differ for each species of seed–litter combination.

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